disk the seat of progressive atrophy. Absolute amaurosis of both eyes—not the faintest perception of light. The scar on the forehead was still visible, but was not sensitive on pressure, and will, probably, entirely disappear. The urine was examined, and gave sp. gr. 1020, acid reaction, and deposited abundant phosphates.

Large doses of potass. iodid. were given to this child for a period of three weeks, and a daily hypodermic injection of strychnia nitr. commencing with gr. $\frac{1}{120}$ and increasing the dose to gr. $\frac{1}{60}$, but with absolutely no effect upon the vision. On October 10, the patient was suddenly taken with high fever, violent headache, and screaming, but there was no vomiting or diarrhœa. The fever and headache lasted four days, and then the child as suddenly recovered.

47 EAST 23D STREET, N. Y.

ARTICLE V.[1]

ON THE FUNCTIONS OF THE CEREBRAL LOBES. By B. F. LAUTENBACH, M.D., Demonstrator of Physiology in the University of Pennsylvania.

THE extirpation of the lobes of the cerebrum is a comparatively easy operation which in previous times has been made by Flourens,[2] Magendie,[3] Hertwig,[4] Longet,[5] Schiff,[6] and others. These older investigators arrived at the conclusion, that, following this operation, the movements are either not affected or only evanescently weakened. The functions depending on the volition and perception are completely abolished. Flourens found that pigeons with both hemispheres removed no longer fear fire. The irritation produced by pinching, pricking, or even burning the operated animal, causes it to be agitated slightly. If the irritant, however, be a second time brought towards the animal it fears it not, and makes no effort to escape from it. These animals have evidently lost their power to memorize the impressions received. The author has frequently observed that cats, in whom the cerebral lobes had been removed, no longer manifest the usual signs of fear and of extreme agitation when a dog approached them. Flourens concludes that memory, vision, audition, and volition, disappear with the removal of the hemispheres.

Schiff believed that the extirpation of the peripheral brain-substance only prevents the occurrence of those movements which proceed from excitation of the higher senses.

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[1] This paper was read before the Alumni Association of the Auxiliary Department of the University of Pennsylvania.

[2] Fonctions du Système Nerveux, Paris, 1842, pp. 31–37.

[3] Leçons s. l. Fonct. d. Syst. Nerv., Paris, 1839.

[4] Exper. de effect. lesion. in partibus Encephali, Berol., 1826.

[5] Traité de Physiologie, tome 2, part 2.

[6] Lehrb. d. Muskel u. Nervenphysiologie, Lahr. 1859.

Birds bear the extirpation of the hemispheres very well, and frequently live for months thereafter. Bischoff[1] gives an account of a male pigeon in whom the whole of the hemispheres, excepting a small portion near the olfactory lobes, had been removed twenty months previously. Movements and flight without known external cause still occurred. Irritations produced reflex movements. The animal had to be fed and forced to swallow. In the course of time the pigeon learned to pass by obstacles instead of running against them, as is usually the case in the animals thus operated upon. It never could be frightened, nor could it ever be sexually excited. Mammals, and especially those animals in whom the operation had been very successful, frequently die in some hours, owing to their recklessly rapid and strong movements causing them to come in contact with hard objects, so that the bleeding, which had ceased, commences again. The blood pressing on the base of the brain produces paralysis of the respiratory centres, and, consequently, death.

In carrying our researches further into the history of the investigations on the functions of the cerebral lobes, we find that, in 1866, Simonoff[2] saw marked evanescent diminution in the sensibility of animals in whom he had stuck needles into the anterior lobes of the brain.

We now come to the more recent and more successful investigations on this subject. Why the previous investigators failed to observe the phenomena described by their successors was probably due to the circumstance that the older authors never really extirpated the whole of the hemispheres, but usually left the lower and anterior portions intact. The latter, it is now stated, is of great importance in the production of movements.

In 1870, Fritsch and Hitzig[3] published a paper on the electrical excitability of the hemispheres. These experimenters carefully removed the convexity of the calvareum without implicating the venous sinuses, which are so readily injured in all operations on the brain. The cortical substance was now galvanically and faradaically irritated. Irritation of the posterior portion of the cortical substance had no apparent effect, while irritation of certain portions of the anterior lobes produced movements in various groups of muscles in the opposite extremities. This so-called "irritable zone" is largely included in the lobi præ- and post-frontales. The extirpation of these "centres" produced an uncertainty in the movements of the extremities of the side opposite to that on which the extirpation had been made. "A slipping away of these limbs occurred without any demonstrable effect on the sensations of the part." It seemed as if the knowledge of the existence of the involved limbs had diminished.

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[1] Sitzungsber. d. k. Akad. in München., 1863, pp. 479 and 569.

[2] Simonoff, Arch. f. Anat. u. Phys., 1866, pp. 545.

[3] Arch. f. Anat. u. Phys., 1870, p. 300; 1871, p. 771; 1873, p. 397. Hitzig, Unters. ueb. d. Gehirh., Berlin, 1874. Centralbl. f. d. Med. Wissenschaften, 1874, p. 548. Arch. f. Anat. u. Phys., 1875, p. 428.

Ferrier,[1] in 1873, published a paper in which he makes use of the discovery of Fritsch and Hitzig, giving no credit, however, to these investigators. His results corresponded in many respects to those obtained by the German experimenters. To this author belongs the credit of popularizing the doctrine of the irritability of the cortical brain-substance. His experiments on monkeys are especially interesting, as he obtained results analogous to those obtained in the lower animals.

By far the most important paper which has thus far been published on this subject is that of Schiff;[2] which seems, owing to its having been published in Italian, to be almost unknown. This author made more than a thousand experiments on the motor functions of the hemispheres, and came to the conclusion that the phenomena following irritation of the Hitzig "centres" are *reflex*, and that the irritated portions of the cortical substance are *centres of sensibility*, for the following reasons:—

"1. The movements resulting from the irritation are prevented by profound etherization, and also by placing the animal under the influence of morphia.

"2. The movements do not occur when the animal is placed in a state of apnœa.

"3. Tetanical irritation of these centres does not produce tetanus in the muscles.

"4. The induction current has less effect than the galvanic current—the opposite being the law for the motor nerve fibres.

"5. The latent time, *i. e.*, the time which expires from the moment of the irritation to the commencement of the contractions of the muscles, is proportionately from seven to eleven times greater following the irritation of the hemispheres than when the sciatic nerve is irritated.

"6. The results of the extirpation of these centres are those of interference with the sensibility."

Eckhard[3] found that when the gray substance of the hemispheres was removed at the "irritable zone," and the white substance beneath irritated, the same result was obtained as if the gray matter was irritated. Burdon-Sanderson[4] says that irritation of the corpus striatum, after the peripheral ganglia had been removed, still produced movements in the muscles. Gliky,[5] however, found irritation of the corpus striatum not to produce movements, but these follow irritation of the fibres which pass around this ganglion, which fibres can be traced into the pes pedunculus.

Carville and Duret[6] say that "extirpation of the nucleus caudatus produces stiffness in the opposite extremity; but when in addition the peripheral centres for this extremity are extirpated, complete paralysis(?) is produced." These authors found the irritation of the hemispheres to produce no effect if the pedunculus was cut. They, as well as Hermann,[1] have shown that the "paralysis" following the extirpation of Hitzig's "centres" is not permanent.

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[1] West Riding Lunatic Asylum Med. Reports, vol. iii. 1873. Proceedings of the Roy. Soc., vol. xxii. p. 229, and vol. xxiii. p. 409. The Functions of the Brain, New York, 1877.

[2] Lezione sop. il Systèma Nervoso Encephalico, Firenze, 1874.

[3] Eckhard's Beitr. z. Anat. u. Phys., vii. p. 127 (1874).

[4] Centralbl. f. d. Med. Wissenschaften, 1874, p. 513.

[5] Eckhard's Beitr. z. Anat. u. Phys., vii. p. 177.

[6] Arch. de Phys. norm. et Path., 1875, pp. 136 and 352.

Brown-Séquard[2] cauterized the convexity of the anterior lobes of the cerebrum with a hot iron, and obtained the same symptoms in the eye and ear of the same side, as was produced by section of the sympatheticus. This author obtained these results only when the cauterization was made on the right side. The cauterization of the left side did not produce the same symptoms. Brown-Séquard says that the result obtained may have been due to "irritation of the trigeminus fibres in the brain-substance." Removal of the cortical substance did not have the same effect. By this method of irritation Hitzig's movements were never produced. On recovery these animals were in the peculiar epileptiform condition described by this author some years since, following section of the sciatic nerve.

Soltmann,[3] of Breslau, making but few experiments owing to the want of the proper animals, found that irritation of the Hitzig "centres" in new-born animals produces no muscular contractions. "When the animal was ten days old, and especially after the thirteenth day, the movements could be produced." Where the "centres" were destroyed in such young animals, no diminished motility resulted.

Soltmann believes the results of the irritation of the cortical "centres" of Hitzig to be due to an irritation of the deeper lying organs of the brain.

Goltz,[4] in a long series of extirpation experiments, obtained results similar to those obtained by Schiff. He observed a marked diminution in the sensibility, which diminution disappeared within a short time after the operation. In conclusion this author says: "No muscular paralysis follows this operation," though he extirpated with the rest of the hemispheres the Hitzig "centres."

From a pathological standpoint numerous[5] arguments in the shape of autopsies have been brought forward, both in support and in opposition to the motor functions of the hemispheres.

In the author's experiments the apparatus employed was a battery of from two to six small Daniell elements, connected with two needles which were applied to the parts of the brain to be irritated. The wire from the battery to the brain had a "Valentin hammer" interposed, by means of which the irritating current could be made or broken at will. Owing to the great liability of error arising therefrom, the induction current was never made use of.

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[1] Pfluger's Arch. f. d. gesam. Physiologie, x. 77.

[2] Arch. de Phys. norm. et Path., 1875, p. 177.

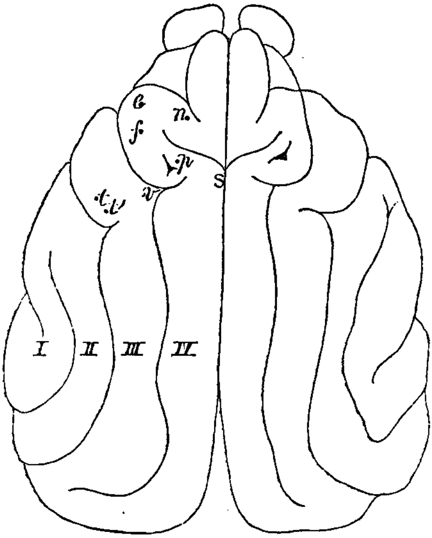
[3] Jahrb. f. Kinderheilk., xi. p. 1.

[4] Pfluger's Archiv, xii. p. 1; xiv. p. 412.

[5] Wernher. Virchow's Arch. B. 56, p. 289; C. Stark. Berl. Klin. Wochenschr. xii. 33, 1874; Samt. Arch. f. Psych. u. Nervenk., 1875, B. 5, p. 201; A. Frey, Arch. f. Psych. u. Nervenk. 1876, B. 6, p. 327.

Irritation of the extreme anterior portion of the cortical substance of the brain produced no apparent effect. As this portion of the brain is very probably concerned in smell, it is evident that, even if this sense had been excited, there are no means known at present by which this excitation can be determined. Ferrier, however, will not confess to a similar ignorance, as he, in speaking of his experiments on apes, locates the sense of smell in the gyrus uncinatus, at the lower portion of the parietal lobe. This to the author seems quite possible, as the fibres from the olfactory lobes pass through this gyrus on their way to the anterior commissure, where they decussate. The criterion that Ferrier went by to determine this excitation of the sense of smell will certainly not be accepted by the majority of physiologists. He drew his conclusion from the irritation of the gyrus uncinatus producing movements of the nasal orifice. For the same reason we might as well say that the "centres" whose irritation produces movements of the orbicularis palpebrarum were the "centres" for the sense of sight.

Fig. 1.



The hemispheres of a dog.—*I. II. III. IV.* The primitive convolutions. *v.* The centre for sight. *e.* The "centres" for the extensors and adductors of the anterior extremity. *f.* For the flexors and rotators of the same. *p.* For the muscles of the posterior extremity. *t.* For the muscles of the face. *n.* For those of the posterior cervical region. *s.* The sulcus cruciatus.

There exist in the dog and in the cat four primitive convolutions arching around the fissure of Sylvius. The fourth convolution describes around the sulcus cruciatus (*s*) an arch. From the irritation of the region here included, and also from irritation of the anterior portion of the third convolution, movements of the muscles of the opposite side of the body have been said to occur. This "irritable zone" corresponds in man to the posterior two-thirds of the frontal and the anterior portion of the parietal lobe.

Mechanical irritation of this region in frogs, guinea-pigs, cats, and dogs, I found not to produce the slightest movement. Chemical irritants also fail to produce movements depending on the local irritation of the "centres." In my experiments neither aqua ammoniæ nor acetic acid were able to produce movements when placed on any portion of the cortical substance of the brain.

Galvanical irritation of the cortical substance of the fronto-parietal lobes of dogs and cats produced the movements observed by the previous experimenters. These movements are, however, nought else than tremors of the muscles, for which the irritated part has been said to be centre. These tremors do not in the least resemble the movements following irritation of the nerves; the latter producing decided contractions or extensions of the respective groups of muscles.

The same tremors are, however, produced by irritating the posterior columns of the spinal cord; so that, were a person to see these movements and not know at what point the irritation was made, he would find it impossible to say whether the irritant was applied to the brain or to the cord. The irritation of the posterior columns not only produces tremors posterior to the point of irritation, but *also of the muscles anterior to this point.* This shows conclusively that these tremors are the results of a reflex action, for, were they due to a direct conduction of the irritation along motor fibres, they would only have occurred in the muscles posterior to the point irritated.

The movements or tremors of the muscles following irritation of the cortex of the brain occurred in a number of experiments, not only on the opposite side of the body to the hemispherical irritation, *but also on the same side.* Thus far I have observed these movements of the muscles on both sides of the body following one-sided irritation only in cats, but there is no reason to doubt their occurrence in other mammals also.

Having seen that irritation of these "centres" produces movements, it was necessary before studying the mechanism of their production to determine the effects of their extirpation. For this purpose I made an opening into the skull just large enough to introduce a needle, and with this needle either the cortical substance alone or portions of the hemispheres and corpus striatum below it were destroyed. In other experiments I destroyed these "centres" by means of chromic acid or ammonia, which, by killing the parts to which they were applied, produced the same effect as the extirpation of these parts. The ammonia method possesses the advantage that the cortical substance can again recover its functions after a comparatively short time.

When by one of these methods the so-called "centres" were destroyed, the animal, after its recovery from the etherization, on first sight presented no symptoms, but, observed more closely, there appeared to be a weakness in the extremities opposite to the side of the operation. This is due, however, not to a weakness of the muscles, for when the animal walks fast it shows absolutely no symptoms. The integrity of the muscular power is unaffected; the animals can stand, walk, run, and jump. Such an animal can do these, but how he does them is another question. He stands, but the limbs opposite to the side on which the operation has been made slip slowly from under him, as if the floor was of oiled glass. When the feet of the unaffected side are placed on their dorsal instead of on their plantar surfaces, the animal immediately returns them to their normal position. If, however, the feet of the affected extremities were placed in contact with the floor on their dorsal instead of on their plantar surfaces, they remained in this position for a long period of time, in fact up to the time when the next general movement took place. This evidently shows that the animal is unable to feel the floor or to know the unnatural position in which its limbs were placed.

The animal walks, not by dragging the affected limbs as it would do were a true paralysis the cause of the trouble, but the leg is thrust out with force and comes down suddenly, resembling very closely the step of a rooster. In walking the dorsal surfaces of the affected feet are just as frequently brought in contact with the floor as are the plantar surfaces. These animals run as they did in their normal state, and in running no difference exists between the two limbs. Jumping is also performed as it is by a normal animal, but on reaching the ground the animal falls over on the affected side, owing to the slipping away of the limbs.

For a physiological illustration of the same phenomena as these which follow the extirpation of the Hitzig "centres," we have merely to examine the symptoms following the section of the posterior columns of the spinal cord. The section of one of these columns causes the limb of the *same side* to present the same change in its functions as if the cortical "centres" for this posterior limb had been removed. The symptoms following section of the posterior columns have repeatedly been shown by physiologists to depend on a loss of the tactile sense. The same loss of tactile sense is observed in locomotor ataxia, in which disease it is chiefly the posterior columns which are diseased. In this malady we see the same want of knowledge of the position of the limbs and the peculiar, heavy sort of walk as we see in animals following section of the posterior columns or extirpation of the "irritable zones." No one at present thinks of speaking of tabes dorsalis as depending on paralysis of the muscles; yet, when the same symptoms are produced in animals by extirpating the "irritable zones," physiologists agree in saying that they show that paralysis of the muscles has been produced by the operation. This want of knowledge of what has previously been determined in physiology and pathology, on the part of even experienced physiologists, is to blame for this as well as for many other evidences of superficial observation.

General sensibility and sensibility on pressure are slightly modified immediately after the extirpation of the "centres," but this impairment, in a very short time, disappears, and may be replaced by a condition of hyperæsthesia.

The paralysis of the tactile sense continues unchanged for about ten days subsequent to the operation, when it commences to disappear, and disappears entirely inside of four weeks. In the posterior extremities the time occupied in recovering is longer than for any other portion of the body. The disappearance is not due to a regeneration of the destroyed nervous substance, but to another portion of the brain taking on itself the functions of the portion destroyed. To this conclusion I have been led by the circumstance that, when the symptoms of the loss of the tactile sense have entirely disappeared, some weeks after the removal of the "centres," careful irritation of the portion of the brain where these centres were, failed to produce tremors of the muscles.

Having seen that the symptoms following the extirpation of the Hitzig "centres" are those of loss of the tactile sense, and that the irritation of the brain in the vicinity of the sulcus cruciatus, where these "centres" have been located, produces an effect not in the least resembling that following irritation of a motor organ, but corresponding in every respect to the effect produced by irritating the posterior columns of the spinal cord, which have been shown to be concerned in the carrying the tactile sense impressions to the nervous centres; we must now attempt to determine whether the symptoms following the irritation depend on the effect produced on the cortical substance or on deeper lying portions of the brain.

The following arguments can be used in favour of the latter and against the former manner of viewing this subject:—

1. As yet we know of no nervous centre—the posterior columns of the cord must be viewed as nerves and not as centres—which are irritable.

2. Extirpation of the cortical substance of the brain, does not prevent irritation of the medullary substance beneath, causing the tremors in the muscles. The tremors, however, no longer followed the irritation, in my experiments, when the anterior portion of the corpus striatum had been destroyed from the side, which operation had the same influence as extirpation of the "centres." Though the tactile sense in these animals returned after a time, yet irritation of the "irritable zone" no longer produced the characteristic muscular movements.

3. When the electrodes were covered with wax, excepting at their point, and then gradually sunk into the brain, the effect of the irritation *increased* as they neared the corpus striatum.

4. Though the loss of the tactile sense does not follow destruction of the

corpus striatum alone, it always followed destruction of the fibres which pass around it in the so-called "vormauer." (Meynert.)

None of these reasons are sufficient to prove that Hitzig was not right in calling the irritable portions of the hemispheres, centres, as my experiments only go to show the continuity in function of the adjacent portions of the brain in their vicinity. But, on the other hand, there is no proof of their being really the parts irritated. The experiments before alluded to, where I destroyed the tactile sense by applying chemical agents to the hemispheres, do not absolutely indicate that the destruction of the cortical substance produced this loss, as we are not able to prove that the agents applied did not also influence deeper lying portions of the brain.

From this it will be seen, that for the present, it is impossible to say whether the so-called "centres" are irritable or not; but this is also in the main immaterial. A subject of much more practical interest, determined in my experiments, is the course which the fibres of so important a portion of the spinal cord as the posterior columns take in the brain.

Schiff[1] has physiologically traced portions of the nervous system possessing the functions of the posterior columns of the cord, into the medulla oblongata, where they more and more take a position to the side, so that on a level with the fourth ventricle they appear to be a continuation of the lateral columns. Stilling,[2] in his anatomical researches, arrived at the same results. It has generally been supposed that the decussation of these fibres takes place in the medulla oblongata; but experiments which I have made have convinced me that in large portion they decussate much higher in the brain.

The following experiment shows this most beautifully:—

A dog, nine months old, while under ether, had 15 ♏ of blood taken from its jugular vein, injected into its brain on the left side, involving and destroying, as was determined at the autopsy, the fibres just below the corpus striatum which form the upper origin of the pes pedunculus. After recovering from the effects of the ether the animal showed the loss of the tactile sense in the extremities of the right side, *i. e.*, the side on which the operation had been made. On feeding the animal I found it to have loss of the tactile sense on the left side of the mouth, from which, though there was no motor paralysis, the milk continually flowed. On giving the animal a bone, he cannot take it on the left side, but readily snaps it up when presented on his right side. As these symptoms occurred on the left side, it shows that crossed paralysis of the tactile sense fibres of the trigeminus occurred, and consequently these fibres must decussate lower down in the brain than the other fibres for the extremities. The temperature was much higher on the side opposite to that on which the injection had been made.

In four days the symptoms manifested in eating had disappeared. In seven days the symptoms in the right anterior extremity had diminished, disappearing in two weeks; those in the posterior extremity still continued for about a week thereafter.

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[1] Schiff, Lehrb. d. Phys., i. p. 301, 1859.

[2] Stilling, Ueb. d. Textur d. Med. Obl., Erlangen, 1842.

This very difficult experiment succeeded on two other occasions, in one of which Dr. Abbot kindly assisted the author.

These experiments show, that, while crossed involvement of the tactile sense follows lesion or extirpation of the nervous elements above the corpus striatum, and still occurs for the manifestations of the sense in the vicinity of the mouth, when the origin of the pes pedunculus immediately below the corpus striatum is destroyed; it no longer occurs in the latter instance for the extremities, the tactile sense in the extremities being found abolished on the side corresponding to that of the lesion. The decussation of these fibres for the extremities must therefore have taken place either in or around the corpus striatum. That it did not take place in the corpus striatum was shown by other experiments where destruction of this nervous organ, without destruction of the fibres around it, produced no loss of the sense of touch. Where does this decussation take place? On examining a horizontal section of the brain of a mammal made at the anterior portion of the optic thalami, we find that fibres from the fan-like terminations of the pedunculi in the cortical substance of the brain—constituting the first projection system of Meynert—enter the thalami. Some of these fibres decussate with those of the opposite side immediately on leaving the thalami, and pass into the opposite pes pedunculus. It is to be observed that the fibres which come from the cortical substance to the thalami optici largely pass around the corpora striata. These anatomical facts were sufficient to cause the author to examine whether or not these fibres were a continuation of those which he had traced from the so-called motor centres to the vicinity of the corpus striatum, and which correspond in function to the posterior columns of the medulla spinalis. If this were so, destruction of one thalamus would produce the same effect as extirpation of the "irritable zone" on the same side, or of the posterior column of the opposite side.

For the purpose of destroying this ganglion a small orifice was made in the posterior parietal region, and then by means of a needle the thalamus was partially destroyed. Destruction of the whole thalamus was never attempted by this means, as it was not only unnecessary but would have led to error through the consentaneous destruction of contiguous portions of the cerebrum. In other animals one or both thalami were destroyed by injecting aqua ammoniæ coloured with carmine; the latter having been added to show at the autopsy the extent of the injury produced.

In the dogs and cats thus operated upon the same symptoms were produced as followed removal of the cortical "centres" on the same side or section of the posterior column of the opposite side.

A cat in whom the fibres around the left corpus striatum had been destroyed showed loss of the tactile sense on the right side. About three weeks later two minims of ammonia were injected into the optic thalamus of the right side, which caused loss of the sense of touch on the left side, in addition to the previous abolition of this sense on the right side. It must be stated in parenthesis that in destroying these ganglia no portion of the "irritable zone" was involved. *After the destruction of these two portions of the cerebrum irritation of the "irritable zone," as well as irritation of the posterior columns of the cord, failed to produce the characteristic tremors.*

This absence of the irritability of the posterior columns I have frequently observed when in both hemispheres the Hitzig "centres" had been extirpated.

As irritation of the "irritable zone" failed to produce movements when the thalamus of the same side was destroyed, we can infer that the fibres from this portion of the cortical substance pass through the thalami optici on their way to the motor centres, as is shown in Fig. 2. Why not consider these fibres passing through the optic thalamus as centripetal instead of centrifugal fibres? For the simple reason that if the fibres from the posterior columns (*d*) passed through the thalami on their way to the peripheral brain "centres," the destruction of these ganglia could not prevent irritation of the so-called "motor centres" from producing movements, as their connection with the motor fibres would still be intact. But, as we have just seen, the opposite is true, and irritation of the Hitzig "centres" has no effect if the thalamus of the same side has been destroyed.

Fig. 2.

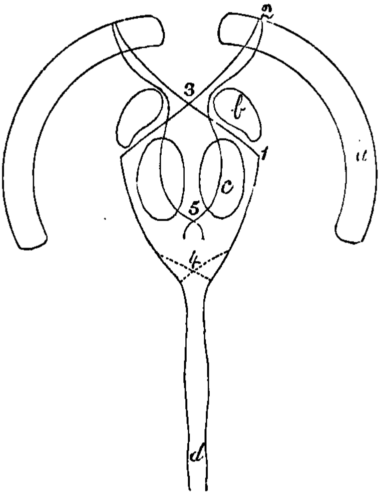

Diagram of the course of the tactile sense fibres in the central nervous system.

It affords me great pleasure to be able to point, in confirmation of the results obtained on the optic thalamus, to the older experiments of Schiff[1] and Nothnagel,[2] who observed the symptoms following the destruction of this ganglion, which I believe to be due to the destruction of the fibres concerned in the sense of touch on their way to the motor centres, wherever these may be.

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[1] Lehrb. d. Physiologie, i. p. 342, 1859.

[2] Virchow's Archiv, lxii. p. 204.

It may be stated that the excitative motor centres must lie in a portion of the brain below the corpora quadrigemina, as the author found that section of the whole brain on a level with these organs fails to prevent those movements which are usually called voluntary.

a represents the cortical brain-substance; *b*, the corpus striatum; *c*, the optic thalamus; *d*, the posterior columns of the spinal cord, which, at the point 1, have not yet decussated, but they decussate, as will be shown hereafter, on their way to the "irritable zone" (2) in the corpus callosum (3). 4 represents the low decussation of the tactile sense fibres for the face; 5, the anatomically determined decussation of the fibres passing through the optic thalami.

The posterior columns (*d*) have been shown not to have decussated at a point (1) immediately below the corpus striatum (*b*). Destruction of the fibres at this point produces loss of the tactile sense on the side of the body corresponding to that of the operation, while extirpation of the "irritable zone" (2), or of the optic thalamus (*c*), produces the same symptoms on the side opposite to that of the extirpation. Consequently there must be a decussation of the fibres from *d*, before reaching the point 2. It seemed possible to the author that this decussation occurred in the corpus callosum (3). If this were so, galvanical irritation of this organ would produce the peculiar tremors in the muscles which follow irritation of the "irritable zone," or of the posterior columns. In a number of experiments where I carefully irritated the *whole* of the corpus callosum, these tremors occurred in *all* the muscles of the extremities. It must be stated, however, that irritation of the posterior portion of this nervous organ does not produce these characteristic symptoms, but both electrodes must be well placed in the anterior and middle portion.

Destruction of this body produces the same symptoms as destruction of the Hitzig "centres," or the section of the posterior columns of the spinal cord. A dog, æt. seven weeks, in whom I had destroyed the anterior and middle portions of the corpus callosum, lived eleven days after the operation. The symptoms observed were those of loss of the tactile sense on *both* sides of the body, but with no apparent change in the other senses. Irritation of the Hitzig "centres" continued to produce the peculiar muscular tremors, which irritation of the posterior columns no longer did.

These experiments show—

1. That the tactile sense fibres for all the extremities are to be found in the corpus callosum, in which they decussate on their way to the hemispheres.

2. That the fibres from the "irritable zone" do not pass through the corpus callosum on their way to the optic thalami. Did they pass through

this body its destruction must have prevented irritation of the "irritable zone" from producing the muscular tremors; but, as we have just seen, they were not prevented by this operation.

In man congenital absence of the corpus callosum seems to have the same effect as its extirpation has in animals. Chvostek[1] reports a case, the symptoms very closely resembling those of locomotor ataxia, in which the posterior columns presented no signs of disease, but the greater portion of the corpus callosum was absent.

By means of the experiments alluded to in this paper, we can trace the fibres from the posterior columns of the spinal cord to the "irritable zone" of the opposite hemisphere through the corpus callosum. From here they go on their way to the motor centres, around the striated bodies through the optic thalami. The fibres from the optic thalami seem anatomically to decussate immediately on leaving these ganglia.

The results obtained in the author's experiments show that the tactile sense impressions produce movements by a sort of reflex action. As regards the optic thalami this coincides with the conclusion arrived at by Meynert,[2] from his anatomical, and Schiff[3] and Nothnagel,[4] from their physiological researches. These authors believe the optic thalami to be organs concerned in reflex action.

The effects of the irritation of the "centres" of Hitzig are due to the irritation of the fibres concerned in the tactile sense, on their way to the centres of motion.

If the movements following irritation of the posterior columns of the cord, or of the "irritable zone" of the hemisphere, be due to reflex action, they must cease to occur when through various agents these reflexes are prevented. One of the means by which this can be done is by profoundly etherizing the animal. Under these circumstances the author found that galvanical irritation of the posterior columns produced no movements. For the "irritable zone" of the hemispheres, Schiff obtained the same results as Hitzig did later; but recently Albertini affirms that he was unable to prevent the movements by etherization. This experimenter could not have produced profound etherization, as in a large number of experiments the author found, under these conditions, that irritation of the "centres" produced no movements whatsoever. In recovering from the etherization a long time elapses before the hemispheres again become irritable. The latter circumstance is easily explained when we recollect the actions of a person or animal recovering from profound etherization. Their walk resembles that of a case of tabes. If a pin be given such a person, it drops to the floor, owing to the sense of touch still being abolished.

The same effects were seen in animals profoundly narcotized or chloroformed. Nicotine and morphia prevent the irritation of the hemispheres from producing the characteristic movements; and I have no doubt that all substances which destroy sensibility will prevent these movements.

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[1] Wiener Med. Wochenschr., 1873.

[2] Wiener Med. Jahrb., 1872, p. 188. Psychiatrisches Centralbl., 1873, March.

[3] Lehrb. d. Physiologie, p. 342.

[4] Virchow's Arch., lxii. p. 214.

Repeated respirations rapidly following one another produce, as is well known, a state of insensibility. Under these circumstances, irritation of the hemispheres produces no movements.

As the author has recently shown,[1] a dog in whom the vena porta has been tied, passes rapidly into an anæsthetized state. In such animals, neither irritation of the posterior columns nor of the hemispheres produces any effect.

Reflex actions must be divided into those which are *innate*, and those which are *acquired*. It is not very probable that the reflex activity resulting from the sense of touch was already possessed by the animals at birth, as the sense itself is an acquired one. Who has not with interest observed a young babe in its attempts to hold an object in its hand, which owing to the absence of this sense it is unable to do; or the first attempts it makes to get its fists into its mouth, striking in its efforts points at a considerable distance from this organ. After a time, however, the child *acquires* the faculty of executing these movements without difficulty.

If the reflexes alluded to are acquired, irritation of the "irritable zone" of the hemispheres of a new-born animal, in whom the tactile sense does not exist, would have no effect; nor would extirpation of these centres produce the characteristic symptoms which would follow their extirpation at a later period of life.

In two cats, aborted about six days before the normal end of gestation, the "centres" were irritated without producing any of the characteristic tremors.

In dogs, cats, and guinea-pigs, taken immediately after birth, I irritated the centres, and no tremors were produced. The "centres" on one side were then extirpated, when on comparing the extremities and face on the two sides no difference in their condition was to be observed.

In cats and guinea-pigs the symptoms caused by the irritation and the excision of the "irritable zones" occur in the fourth week, at which time these animals acquire the sense of touch. In the twenty-seven young dogs on whom I experimented, the symptoms did not appear until the end of the fifth week. This corresponds to the fact that the dog acquires the sense of touch at a later period than the cat.

A young dog in whom I extirpated the "centre" for the left posterior extremity showed no symptoms up to the forty-first day, when they appeared without any new operation being made. Five weeks later the symptoms had again disappeared. I have endeavoured to repeat this observation, but always without success, owing to the animals, when operated on so young, dying from inanition in a few days.

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[1] Phila. Med. Times, May 26, 1877.

In concluding this portion of the subject under discussion, it is necessary to state, in contradiction to previous investigators, that there exists also in the frog an "irritable zone" of the hemispheres with functions analogous to the same in the higher animals. This irritable portion of the hemispheres is confined in the frog to the portion immediately over the tympanum. Much care was necessary in experimenting with these animals, owing to the greater proportionate development of the spinal cord, as compared to that of the brain, making it very difficult to prevent spinal reflexes from interfering with the results.

Conclusions.—1. Irritation of the posterior columns of the spinal cord, of the corpus callosum, or of the so-called "irritable zone" of the hemispheres, produces tremors of the muscles which are due to irritation of sensory fibres before they enter the motor-centres.

2. All substances which destroy sensibility prevent the irritation from producing these tremors.

3. Section of the posterior columns produces loss of the sense of touch on the side corresponding to that of the lesion. Destruction of the corpus callosum produces this effect in the extremities of both sides of the body; while extirpation of one of the "irritable zones," or of an optic thalamus, produces the loss of the tactile sense on the opposite side from that of the operation.

4. None of these operations produces motor paralysis.

5. The reflex movements which are destroyed by the extirpation of the "centres" of Hitzig, or by one of the operations just mentioned, are of the acquired variety, as they do not exist in the animal at birth.

Influence of the Hemispheres on Vision.—Immediately below the "centre" for the posterior extremity there is a portion of the hemispheres, the extirpation of which, in the author's experiments, always produced blindness in the eye of the opposite side (Fig. 1, *v*). The removal of this centre in both hemispheres resulted in complete blindness, from which the animal never recovered while under observation. Blindness resulted from this operation in very young animals, as well as in those which were full-grown.

Influence of the Hemispheres on the Temperature.—In a number of experiments it was found that irritation, by ammonia, of the parietal lobes produces a great diminution in the temperature of the body. This decrease in the temperature, measured in the rectum, frequently amounted to 8° F. While the temperature of the body decreased in this manner, that of the extremities greatly increased, so that one could see the feet become redder and warmer when the irritant was applied.

This effect may have been due to an irritation of the sensory nerves of the membranes, or those of the brain itself, as it is a well-known fact that irritation of a sensory nerve will through its influence on the vaso-motor centres produce an increased arterial pressure, and consequently an increase in the peripheral temperature. But if this were so, why does not the decreased temperature in the rectum follow irritation of other portions of the cortical substance of the brain. The cause most probably lies in the effect of the irritation on the brain-substance itself.

Influence of the Hemispheres on the Circulation.—According to Schiff,[1] the irritation of a large portion of the hemispheres commencing posterior to the olfactory lobes, produces a very marked increase in the pulse, amounting to eighteen pulsations per minute. This did not occur if the vagi had been cut at the plexus ganglioformis.

I have as yet not had the opportunity to repeat these experiments, but see no reason to doubt the results obtained by Schiff, especially as it is a well-known fact that tying both the carotids, whose branches are more especially distributed to the hemispheres, produces, through irritation, an increased blood-pressure, and an increase in the number of heart-beats.

The Extirpation of the whole of the Hemispheres.—On this subject I have made but six entirely successful experiments in mammals, partially owing to the difficulty to keep such animals alive, and partially from my finding that the results obtained did not differ from those obtained by Goltz.

In these experiments the skull was trepanned in four different places; and then from underneath the membranes the hemispheres were gradually scooped out by means of a small shovel-like instrument. The removal of the whole of the hemispheres usually occupied but two days. Any bleeding which occurred was stopped by means of the Penghawar Yambi. At the end of a week the observations were commenced in the animals which survived.

The dogs and cats thus operated on have the appearance of being idiotic. Those which have lost almost the whole of the hemispheres walk very seldom, while those in whom less had been removed go about more, but with a short measured step. If such an animal has a bone placed before him, he is only with great difficulty able to find it. If a bowl of milk was placed below the level of the mouth of a cat in whom the hemispheres had been removed, the animal made the lapping movements long before its mouth reached the milk; and when it did reach it, the milk taken ran out from the side of the mouth almost as rapidly as the tongue of the cat brought it into that organ. Goltz observed a dog several days in succession bite himself in the foot while eating, so that he cried out for pain. These animals were never found with bitten tongues.

This operation always produced complete blindness, but this is not the cause of the difficulty in feeding, as a blind dog in possession of his hemispheres has no difficulty in feeding himself. It cannot be said that his better condition is due to the possession of the senses of smell and of hearing, as the animal *sans* hemispheres also possessed these senses unimpaired. There must be some other cause to produce these symptoms. In my opinion they are due to a *loss of all the after-birth-acquired sensations.* The animal loses the power of associating the impressions received with any which had previously been made; or, as it can be more understandingly, though, perhaps, less accurately, expressed, the animal in whom the hemispheres have been removed has lost the power of memorizing.

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[1] Altes und Neues ueb. Herznerven, pp. 94, 104.

A dog who very readily gave me his paw, or sat on his haunches, on giving him certain signs, did not even attempt to do so after its hemispheres had been removed. All attempts to learn him his old tricks proved futile.

When a needle was run through the paw of a dog thus mutilated, he gave evidences of feeling pain by running his nose towards the irritated point, which, however, he was unable to find. He had evidently lost all his acquired ideas of a sense of location.

A normal dog will, when placed in a room, seek a sleeping place, to which he always will return, but a dog in whom the hemispheres have been removed is just as likely each time to take a new bed place.

These animals still evidence thankfulness to the person feeding them, but possess no recollection of this person ten minutes later.

Not a muscle of the body of an animal in whom the hemispheres had been removed was paralyzed.

General sensibility appeared to be uninvolved, though at times there appeared to be a state of hyperæsthesia. The senses of touch, of pressure, and of differences in temperature, were no longer possessed by these animals.

Article VI.

The Anatomy of the Brachial Plexus. By J. F. Walsh, M.D., of Philadelphia.[1]

Four years ago, at the suggestion of my preceptor, Dr. Wm. W. Keen, I commenced the investigation of this subject with the intention to dissect as many plexuses as possible, and to determine from these which of the numerous arrangements described in the anatomical works was most common in the subject, and therefore the normal one. To my surprise, after having made a number of dissections, I found that they did not correspond to any of the descriptions of the books, the nearest approach being to the disposition given in Sappey's work. Being confident, from the care taken, that my results were correct, I was led to the conclusion that the variations

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[1] Extracted from a Thesis presented to the Faculty of the Medical Department of the University of Pennsylvania for the degree of Doctor of Medicine, and awarded one of the prizes, March, 1876. The remainder of the Thesis on the Comparative Anatomy of the Plexus, together with the anomalies found in the human subject, the author expects to present to the Academy of Natural Sciences of Philadelphia.